PLATINUM-GROUP METALS

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Stillwater Mining Company (Billings, MT) was the only domestic producer of primary platinum-group metals (PGMs) from its Stillwater Mine near Nye, MT, and its East Boulder Mine south of Big Timber, MT. Stillwater was majority owned by Mining and Metallurgical Company (MMC) Norilsk Nickel (Moscow, Russia). Stillwater produced 17,700 kilograms (kg) of PGMs in 2004, 3% less than the 18,200 kg that it produced in 2003 (Stillwater Mining Company, 2005, p. 1).

In 2004, the domestic automobile industry continued to be the major consumer of PGMs. Autocatalysts accounted for approximately 85% of rhodium consumption, 50% of palladium consumption, and 43% of platinum consumption. Despite strong vehicle sales in 2004, consumption of palladium declined as automobile manufacturers and electronic component manufacturers made a concerted effort to reduce the palladium content of their products. Purchases of rhodium by the automotive industry for use in catalytic converters increased by 17% to 24,000 kg in 2004 compared with those of 2003 (Kendal, 2005, p. 43). Much of the growth in sales was owing to tightened emissions standards that necessitated an increase in rhodium loadings on autocatalysts. Also, thrifting (the reduction of the particular metal content of a product without compromising its ability to meet relevant operating standards) of palladium and platinum by automobile manufacturers was achieved by increasing the use of rhodium in some catalyst formulations. In 2004, world rhodium supplies were virtually unchanged from those of 2003.

Domestic demand for ruthenium, used primarily in ruthenium-base catalysts and in the manufacture of resistors for the electronics industry, increased by 9% in 2004 compared with that of 2003. After strong demand by the chemical industry for ruthenium-base catalysts in 2003, demand fell by 14% in 2004. The drop in demand by the chemical industry was outweighed by increased demand by the electronics industry. In 2004, the electronics industry purchased 12,000 kg of ruthenium, a 40% increase from 8,620 kg purchased in 2003. Iridium consumption increased by about 9% compared with that in 2003. The chemical industry increased its purchases of iridium for catalysts by 25%. A strong mobile electronics market resulted in an increase in demand for iridium crucibles used in the production of high-purity semiconductor crystals (Kendal, 2005, p. 40-41).

Production

In 2004, two underground U.S. mines owned by Stillwater produced PGMs. Stillwater reported that the Stillwater and the East Boulder Mines produced 13,700 kg of palladium and 4,040 kg of platinum in 2004. Palladium and platinum production were down by 2.4% and 3.5%, respectively, compared with that of 2003. A 10-day strike in July at the Stillwater Mine resulted in a loss of about 780 kg of PGM production. Stillwater defined mine production as the quantity of PGMs contained in concentrate at the time it was shipped to the smelter. The company milled 1,100 metric tons (t) of ore from the mines, 2% more than in 2003. In 2004, the average mill head grade for the mines was 17.3 grams per metric ton (g/t) combined palladium and platinum, compared with 18.2 g/t in 2003 (Stillwater Mining Company, 2005, p. 1, 39).

Stillwater processed ore from the Stillwater Mine through a flotation concentrator adjacent to the mine shaft. The mill had an approximate capacity of 2,720 metric tons per day of ore, and in 2004, the recovery rate for PGMs was 92%. Crushed ore was fed into the concentrator, mixed with water and ground to a slurry to liberate the PGM-bearing sulfide minerals from the rock matrix. Reagents were added to the slurry to separate the valuable sulfides from waste rock in a flotation circuit. In this circuit, the sulfide minerals are selectively floated, reground, and refloated to produce a concentrate suitable for further processing. The flotation concentrate, about 1.5% of the original ore on a dry weight basis, was filtered and transported to the company's metallurgical complex in Columbus, MT. During 2004, the Stillwater Mine produced 9,670 kg of palladium and 2,920 kg of platinum. Ore from the East Boulder Mine was transported by rail haulage to the surface, where it was treated in a process similar to that used for ore from the Stillwater Mine. During 2004, East Boulder produced 3,980 kg of palladium and 1,120 kg of platinum (Stillwater Mining Company, 2005, p. 4-5, 39).

Stillwater's smelter and refinery is located on property it owns in Columbus. The smelter-refinery complex was shut down for 5 weeks in the second quarter of 2004 for rebricking of the smelting furnace. Mine operations continued during the rebricking, and the concentrate produced was stored for processing following restart of the smelter. Concentrate accumulated during the rebricking was processed by the end of the third quarter 2004 (Stillwater Mining Company, 2005, p. 18).

Stillwater's proven and probable reserves are contained in the J-M Reef, a 45-kilometer-long ore body in the Beartooth Mountain Range in south-central Montana. The company reported proven and probable ore reserves as of December 31, 2004, of 37 million metric tons (Mt) with an average grade of 19.5 g/t of PGMs and containing 742,000 kg of palladium and platinum at a ratio of 3.6 palladium to 1 platinum (Stillwater Mining Company, 2005, p. 17).

PolyMet Mining Corporation (Vancouver, British Columbia, Canada) announced that the company had submitted the necessary paperwork for the draft scoping environmental assessment worksheet (EAW) for the NorthMet project, Babbitt, MN. Once the EAW is approved, PolyMet will be required to file environmental impact statements (EIS). If a mine is developed, it would be the first combined base-metal and precious-metal mine in the State of Minnesota and the third PGM mine in the United States (PolyMet Mining Corporation, 2005).

Secondary Production of PGMs.—In 2004, recovery and recycling of autocatalysts provided a growing secondary source of PGMs. The strength of the price of platinum in 2004, which averaged $848.76 per troy ounce, helped support the profitability of the recovery and recycling businesses. In the United States, despite the price increase, production of platinum from catalytic converters rose by only 400 kg in 2004 to an estimated 13,600 kg of platinum.

Stillwater announced in late 2004 that it had entered into a supply contract that would greatly increase its PGM recycling. PGM scrap was obtained primarily from spent autocatalysts with additional material from spent catalytic materials from oil refineries. In 2004, Stillwater increased its secondary recovery of PGMs to 5,130 kg—3,080 kg of platinum, 1,650 kg of palladium, and 404 kg of rhodium (Stillwater Mining Company, 2005, p. 7).

Increased recovery and recycling of autocatalysts was most marked in Western Europe, where improved collection and processing of scrap catalytic converters resulted in the recovery of 4,400 kg of platinum and 3,400 kg of palladium. For several years, the recovery of PGM from scrap catalytic converters in the European Union (EU) has been increasing owing to high PGMs prices and the introduction of legislation to increase scrap-vehicle recycling. The EU end-of-life vehicle recycling directive was to become effective in 2005 and aimed to increase the rate of recovery and reuse of materials to 85% per vehicle by weight by 2006. In several countries, effectively 100% of the cars being recycled were equipped with catalytic converters containing PGM alloys. As for the remaining EU countries, because catalytic converters have only been required on all new gasoline cars since 1993, the proportion of automobiles fitted with catalytic converters being scrapped is increasing as greater numbers of these vehicles reach the end of their lives. Greater quantities of PGMs also were recovered from autocatalysts in Asia and South America because of the higher price (Kendal, 2005, p. 22-23).

Consumption

In 2004, global platinum sales increased by less than 1% to about 205,000 kg as compared with that of 2003, driven by increased use of platinum in catalytic converters and offset by a decrease in platinum demand from the jewelry industry because of the increase in metal price. Increased sales of diesel cars in Europe, rising light-vehicle output, tighter emissions regulations, and greater use of platinum-base catalysts in the United States at the expense of palladium combined to increase the consumption of platinum in autocatalysts by about 7% to 99,200 kg compared with that of 2003. Palladium global sales also increased in 2004 to 205,000 kg, a 22% increase as compared with that of 2003. The increase was driven by the rapid growth of palladium jewelry production in China and growth in use of palladium in autocatalysts, dental alloys, and electronics (Kendal, 2005, p. 3-8, 49).

U.S. apparent consumption of platinum was estimated to be about 72,000 kg, and the net import reliance as a percentage of apparent consumption was 92%. The 2004 apparent domestic palladium consumption was estimated to be 116,000 kg. Net import reliance as a percentage of apparent consumption of palladium in 2004 was estimated to be 83%.

Platinum.—Diesel-powered vehicles have become increasingly popular in Europe and were estimated to have accounted for more than 48% of the new car market in 2004. At the same time, platinum loadings on catalysts for use with diesel engines have increased in an effort to meet European Stage III emissions requirements, which apply to all new vehicles manufactured after 2001; platinum catalysts are more efficient than palladium catalysts in reducing emissions from diesel engines. The use of platinum in diesel-catalyst formulations is expected to account for more than three-quarters of catalyst demand from the European automotive sector by 2007 (Kendal, 2005, p. 3-4).

Global consumption of platinum in jewelry dropped to 68,400 kg, the lowest level since 1997, largely as a result of high and volatile prices. The higher price of platinum led to a significant decrease in purchases of metal by Chinese jewelry manufacturers. Retail demand in China for platinum jewelry also suffered losses to palladium and white gold jewelry. Japanese and North American platinum jewelry sales also dropped in 2004. In Europe, however, sales grew owing to a growth in the British platinum jewelry market and strong sales of Swiss watches (Kendal, 2005, p. 3-4).

Global use of platinum in chemical catalysts grew 3% in 2004, to 10,300 kg, compared with that of 2003. Consumption of platinum used in the manufacturing of catalyst gauze for nitric acid production dropped but was offset by an increase in consumption of platinum-base catalysts by European and Asian bulk and specialty chemical manufacturers. The global use of platinum in electronics increased 13% to 9,180 kg in 2004. Growth in the sales of computer hard disks accounted for much of the growth in consumption, with greater production of PGM-bearing thermocouples and other electronics, adding to the increase of consumption (Kendal, 2005, p. 25-26).

Platinum consumed in the production of liquid crystal displays (LCDs) increased in 2004 by 38%, to 9,020, compared with that of 2003, with most of the consumption in Asia. The total consumption of platinum by the petroleum industry increased in 2004 by 21% to 4,510 kg, driven by the construction of new petroleum refineries. Consumption in other end uses such as oxygen sensors in automobiles, spark plugs, medical components, and coatings on turbine engines increased slightly, while consumption of platinum in dental alloys remained flat in 2004. Consumption of platinum-base catalysts used in stationary emissions controls dropped in 2004. Worldwide consumption of platinum coins increased in 2004 to 1,240 kg; however, U.S. Mint sales of platinum American Eagle Bullion coins fell 20% in 2004 as compared with sales in 2003 (Kendal, 2005, p. 27; U.S. Mint, 2005§[1]).

Palladium.—Worldwide consumption of palladium rose to 205,000 kg in 2004, a 22% increase compared with consumption in 2003. This large increase was met with a similar increase in mine supply. The increase in consumption was driven by an increase in palladium jewelry manufacturing in China and increases in other main applications. Palladium used in jewelry increased almost fourfold, rising to 28,600 kg in 2004, from 7,780 kg in 2003. China alone consumed about 21,800 kg of palladium for jewelry manufacture, primarily in white gold products (Kendal, 2005, p. 8-10).

[1]A reference that includes a section mark (§) is found in the Internet Reference Cited section.

Palladium consumption for the production of autocatalysts grew to 119,000 kg in 2004 from 107,000 kg in 2003. In China, Japan, and the United States, the consumption of palladium in autocatalysts rose because of the increase in automobile production and a shift away from platinum-base catalysts, while consumption in Europe dropped because of the higher use of platinum-base catalysts in diesel-powered vehicles (Kendal, 2005, p. 32).

Consumption in other applications also increased. Palladium consumption in dental alloys grew to 26,400 kg, a 3% increase as compared with that of 2003, with Japan as the major consumer. The price and the properties of palladium made it a perfect fit for restorative dentistry, bridges, and crowns (Rushforth, 2004). The chemical industry consumed 9,490 kg in 2004, a 15% increase compared with that of 2003. The main uses of palladium in the chemical industry were in manufacturing bulk chemicals and in catchment gauze in the nitric acid industry, both of which increased consumption in 2004. The electronics industry increased its consumption of palladium by 7% in 2004 to 29,700 kg. Most of the palladium used in the electronics industry was for multilayer ceramic capacitors in all types of electronic goods (Kendal, 2005, p. 35-39).

Other PGMs.—Global rhodium consumption in 2004 rose by 19% compared with that of 2003, to 23,000 kg. A majority of this was used in the production of autocatalysts. Other uses of rhodium were, in descending order, LCD glass manufacturing, chemicals, electrical applications, and jewelry (Kendal, 2005, p. 40-41).

Global consumption of ruthenium increased 9% to 21,000 kg in 2004. A 40% increase in consumption in electronics was partially offset by a drop in chemical, electrochemical, and other end uses. Consumption of iridium, which is used in similar industries as ruthenium, increased to 3,600 kg in 2004, a 9% increase as compared with 2003 consumption (Kendal, 2005, p. 40-41).

Prices

According to Platts Metals Week, the 2004 annual average price of palladium was $232.93 per troy ounce, which was a 15% increase compared with that of 2003. Prices had been trending down since 2000 when the price was $692 per troy ounce. The average annual platinum price reached an alltime high of $848.76 per troy ounce, a more than 22% increase compared with the average annual 2003 price. As for the other PGMs, the iridium 2004 annual price increased by 99% compared with the 2003 price, the rhodium 2004 annual price increased by 85% compared with the 2003 price, and the ruthenium 2004 annual price increased by 81% compared with the 2003 price.

Palladium.—The price of palladium climbed from $200 per troy ounce at the start of the year to $245 per troy ounce on January 22. The price rise was driven by an increase in fund purchasing and investor speculation. After the peak on January 22, buying slowed and the price dipped to $233 per troy ounce.

The price continued to fluctuate through the end of April based on the balance between speculative and physical demand and supply, ending April at $248 per troy ounce. Increased physical demand from the Chinese jewelry industry and the announced development of a palladium diesel catalyst helped to spur demand. The price spiked to $267 per troy ounce on May 4, before falling rapidly to $233 per troy ounce on May 10, allegedly owing to reduced buying for Chinese jewelry. Through the end of October, the price volatility continued, from a high of $257 per troy ounce at the end of May to a low of $208 per troy ounce in early September. Prices stabilized in November in a range of $212 per troy ounce to $220 per troy ounce. Beginning in December, the palladium market began a period of oversupply, with prices falling as low as $182 per troy ounce and ending the year at $186 per troy ounce, $14 per troy ounce (8%) below that at yearend 2003.

Platinum.—The depreciating dollar led to an increase in speculative investments that kept the price of platinum above $770 per troy ounce for the entire year. With platinum supply nearly matching the physical demand, the platinum investment market was the primary cause of price fluctuation in 2004.

The platinum price opened the year at $836 per troy ounce and quickly started to climb. An increase in purchases of platinum by Chinese jewelry manufacturers, in addition to the increased speculative purchasing, resulted in the price surging to $871 per troy ounce on January 13, before falling to $841 per troy ounce at the end of the month.

In February, fluctuations in the value of the dollar and the Japanese yen led to price volatility. A surge in investment buying in late February led to the price rising above $900 per troy ounce on March 1, and on April 1, the price reached a 24-year high of $940 per troy ounce. By April 19, however, the price had plummeted to $799 per troy ounce owing to a strengthening dollar and contraction in consumer and speculative demand. By May 10, the price had fallen to $771 per troy ounce, the lowest level of the year. Prices continued to be volatile, rising again to $849 per troy ounce on May 29, before weakening again. Prices fluctuated through May and June, but generally traded below $800 per troy ounce. In the third quarter of the of the year, prices continued to fluctuate but generally trended upward and averaged $839 per troy ounce for the quarter, in part supported by several supply disruptions. The announcement that several mine expansions might not happen because the strengthening of the South African rand made expansion too expensive, a workers strike in October at Anglo American Platinum Corporation Limited (Johannesburg, South Africa) and Impala Platinum Holdings Limited (Implats) (Johannesburg) PGM mines, and accidents in South African mines caused concern about the supply of platinum. In the fourth quarter, when the price peaked at $870 per troy ounce and averaged $851 per troy ounce, price fluctuation was spurred by continuing labor problems, a strong rand, and increases in demand. The price ended the year at $863 per troy ounce, $27 per troy ounce (3%) lower than the opening price.

Other PGMs.—The price of rhodium began the year at $500 per troy ounce. The price reached $900 per troy ounce in early March, owing to speculative buying. The sudden price increase, however, caused sellers to release more metal from their inventories, which caused the price to drop to $775 per troy ounce in early April. The price began another surge which ended at an 11-year high of $1,525 per troy ounce in early August owing physical shortage of rhodium. The price spurred the release of metal into the market and again caused the price to drop. The price fell to $1,120 per troy ounce in mid-September before recovering to $1,330 per troy ounce by late-November, where it remained until yearend.

The price of iridium began the year at $87 per troy ounce and remained at this price until early February. The price surged to $230 per troy ounce by mid-March. Many analysts believed this price surge was caused by speculative interest in precious metals. The price for iridium stabilized and started to slide in late April and ended the year at $170 per troy ounce.

The price of ruthenium followed a similar trend to that of iridium in the first half of 2004, starting the year at $41 per troy ounce and quickly surging to $72 per troy ounce by March. The price then fell in mid-March and ended May at $60 per troy ounce, where it remained until the end of July, when the price speculation and an increase in demand led to a surge to $82 per troy ounce in late October. Supplies were adequate, however, and prices again declined and ended the year at $67 per troy ounce.

Trade

In 2004, the U.S. net import reliance as a percentage of apparent consumption was estimated to be 83% for palladium and 92% for platinum. Imports of refined palladium in 2004 increased by 21% to 127,000 kg from 105,000 kg in 2003, with three countries accounting for more than 75% of refined palladium imports in 2004—Russia (35%), South Africa (23%), and the United Kingdom (17%). Imports of platinum, including waste, scrap and coins, decreased by 2% in 2004 to 86,400 kg from 88,500 kg in 2003, with four countries accounting for 85% of imports of platinum in 2004—South Africa (57%), the United Kingdom (17%), Germany (6%), and Russia (5%). Other refined PGM imports were up by 17% in 2004 as compared with those of 2003. South Africa accounted for 68%, the United Kingdom accounted for 15%, and Germany accounted for 9% of other PGM imports in 2004. The United States exported 31,400 kg of palladium (22,300 kg in 2003), 20,000 kg of platinum (22,200 kg in 2003), and small quantities of other PGMs.

World Review

In 2004, world mine production of PGMs increased by about 3% to 467,000 kg compared with 452,000 kg in 2003 (table 5). South Africa, the world's leading producer of PGMs, accounted for 61% of total mine production in 2004; Russia accounted for 27%; the United States and Canada, 4% each; and Zimbabwe, 2%. South Africa, which accounted for 75% of world platinum production, increased its output of platinum by 6% in 2004 to 160,013 kg. Global output of palladium climbed to 188,000 kg, with South Africa and Russia accounting for 42% and 39%, respectively, of the total. South Africa dominated the world's mine production of other PGMs with 75% of the total.

Canada.—North American Palladium Ltd. (Toronto, Ontario, Canada) produced about 9,610 kg of palladium and 782 kg of platinum in 2004 at the Lac des Iles Mine as compared with 8,980 kg of palladium and 738 kg of platinum in 2003. Although the grade of the ore was lower than in previous years, North American Palladium increased the amount of ore processed by installing an additional secondary crusher. Increased throughput and the development of an underground section with higher grade ore located directly beneath the open pit, could lead to almost double production by 2006 (North American Palladium Ltd., 2005).

China.—Chinese growth in light vehicle production and sales and increased emission restrictions resulted in a 10% increase in global demand of palladium and a 15% increase in platinum demand from the autocatalyst industry in 2004 as compared with that of 2003 (Kendal, 2005, p. 22). China was the world's leading consumer of platinum but produced only about 1,000 kilograms per year (kg/yr) of PGM materials. In 2004, China imported 29,500 kg of platinum, which accounted for about 14% of total world mine output (Antaike Precious & Minor Metals Monthly, 2005).

Russia.—In 2004, Russia accounted for 39% of global mine production of palladium and 17% of platinum production. Despite the importance of the Russian PGM mining industry to the world market, information on production, reserves, and sales have historically been difficult to obtain because such data were considered to be confidential under Russian law. Recently, however, Norilsk has been able to disclose some information regarding its nickel and other operations and has made efforts to provide more details on its PGM production, reserves, and sales. In late 2003, a bill to declassify PGM data (with the exception of Government stocks and sales) was enacted. Though the bill was to take effect in February 2004, the publication of PGM data was delayed by regulatory procedures that needed to be followed by several Ministries, and data were not yet available at yearend. Gold data were also considered a state secret and recently reserve, production, and sales information were made available to the public (O'Neil, 2004; MMC Norilsk Nickel, 2005, p. 37-40, 90).

South Africa.—South Africa accounted for approximately 75% of platinum, 42% of palladium, and 61% of all PGMs produced in 2004. In 2004, South African production of PGMs was up by 5% as compared with that of 2003; palladium production rose 8%, platinum production rose 6%, and other PGMs production declined 3%.

Production by Anglo increased to 76,200 kg from 71,800 kg in 2003 and accounted for 27% of the total South African PGM production in 2004. The increase in production in 2004 came from the newer operations and overshadowed the loss of production caused by the 13-day strike at the older Rustenburg, Union, Amandelbult, and Bafokeng-Rasimone Mines. The new western limb tailings retreatment plant, the Rustenburg UG2 project, and the Modikwas joint venture added about 4,700 kg of PGM production in 2004. Anglo also added a one-time benefit of 2,800 kg of PGM from the cleanup operation at is Waterval Smelter near Rustenburg (Anglo American Platinum Corporation Limited, 2005, p. 14-19, 88).

Refined production of PGMs from Implats increased 5% compared with 2003 production, even after a strike in October shut down operations for 10 days, causing a loss of about 1,400 kg. The increase was attributed to a higher rate of ore extraction and increased processing of ore during nonstrike periods (Impala Platinum Holdings Limited, 2005).

At Northam Platinum Limited (Johannesburg), a fire on September 20, which killed nine employees, closed the mine for about 6 weeks; production in 2004 was down by 12% compared with production in 2003 (Kendal, 2005, p. 14-15).

In November, a steam explosion at Lonmin Plc (London, United Kingdom) smelter No. 1 incapacitated the smelter for 2 months. The PGM production was relatively unaffected because Lonmin used older furnaces and shipped the remaining concentrates to the Impala facilities to be toll refined (Platts Metals Week, 2004).

Southern African Resources Plc (SAR) (London) began a prefeasibility study for a 9,300-kg/yr PGM mining operation at its Leeuwkop property in South Africa. The bankable feasibility study was expected to be completed during the first quarter of 2006. Once commissioned, the mine could produce gold, palladium, platinum and rhodium (Platts Metals Week, 2005).

Zimbabwe.—In 2004, Zimbabwe Platinum Mines (Zimplats) (Harare, Zimbabwe), which owns Zimbabwe's Hartley Complex, produced about 2,300 kg of palladium and 2,700 kg of platinum. Plans were developed to start an underground mine below its Ngezi open pit project, aimed at doubling the rate of production at Ngezi to about 12,500 kg/yr of PGMs by 2005. The introduction of an underground component at Ngezi would increase PGMs reserves substantially to about 1.1 million kilograms of PGMs, with a platinum-to-palladium ratio of about 1.2 to 1 (Zimbabwe Platinum Mines, 2005).

The responsibility for all of Zimbabwe's PGM sales was to move to Zimbabwe's central bank, which also handles the sales of gold. Although Zimbabwe has proven to be a popular site for exploration and mining of PGMs, much of the refining takes place in South Africa. This move has made foreign investors reluctant to invest in new operations in Zimbabwe (Kendal, 2005, p. 19).

Current Research and Technology

Most of the primary PGMs come from low-sulfide platinum ores (South Africa) and sulfide copper-nickel ores (Canadian, Russian, and United States deposits). Recent exploration in Russia and elsewhere has resulted in the discovery of some new deposits of PGM-bearing low-sulfide ores. Many existing technologies for treating PGM ore are based on mechanical beneficiation, high temperature smelting and converting operations, and hydrometallurgical processing. The development of a less complex procedure to recover PGMs and nonferrous metals from PGM-bearing low-sulfide ores would decrease operating costs and improve environmental conditions. A process was developed for the production of rich concentrates of precious and nonferrous metals by the treatment of the flotation products from South African platinum-containing chrome ores that involves autoclave leaching, roasting, hydrochlorination, and precious metals recovery by adsorption. Autoclave oxidative leaching allows the nonferrous metals to pass into solution, from which they are recovered as a rich sulfide concentrate (more than 30% copper and nickel). Recovering the precious metals through leaching combines two operations—sinter roasting and hydrochlorination. Roasting of the sulfide concentrate then destroys the precious metal acid-proof mineral forms. The precious metals are recovered from the sulfide concentrate by ion exchange using anionites that are finally burned. The ash from the burning is a concentrate of precious metals (more than 75% in total) which are recovered in three forms: ammonium chloroplatinate with a purity greater than 98%, palladium dichlorodiamene with a purity greater than 96%, and a mixture of iridium, rhodium, and ruthenium hydrates (Platinum Metals Review, 2004).

A fuel cell is an electrochemical device that converts the chemical energy in a fuel (with the aid of a platinum catalyst) directly into electrical energy. An improved design concept for direct methanol fuel cells makes it possible to construct fuel-cell stacks that can weigh as little as one-third as much as conventional bipolar fuel-cell stacks of equal power. Typically, about 80% of the mass of a conventional fuel-cell stack is in the biplates, end plates, and tie rods. The biplates are usually made of graphite composite materials and must be machined or molded to contain flow channels, at a cost that is usually a major part of the total cost of the stack. The new design eliminates the biplates, end plates, and tie rods. Moreover, in comparison with conventional fuel-cell stacks, the new fuel-cell stacks can be assembled, disassembled, and diagnosed for malfunctions more easily. These improvements could help bring direct methanol fuel cells closer to commercialization (NASA Tech Briefs, 2004).

A key factor in the demand for palladium and platinum is their use for autocatalysts. The choice between the two usually depends on the relative price of the metals, but while price is important, the two metals are not interchangeable. A switch from one to the other cannot readily be made in the short term given the long lead time between design and certification of an emissions system and the launch of the vehicle model to which it is fitted. Technical factors, which preclude the use of palladium in autocatalysts for diesel engines, also play a role in the choice. The increased market penetration of diesel cars in recent years, therefore, has been a benefit to platinum demand. On April 2, n.v. Umicore s.a. (Brussels, Belgium), announced the introduction of technology that reportedly will enable the use of palladium as a catalyst in diesel emission systems for passenger cars. The new diesel oxidation catalyst technology may enable the replacement of about 25% of current platinum loadings by palladium, significantly lowering demand for platinum. The actual level of substitution would require about 1.5 times the amount of palladium to achieve the same results of platinum. The new palladium autocatalysts are still in the early stages of development, with results not expected for a number of years, and no immediate effect on platinum demand according to Umicore (n.v. Umicore s.a., 2004).

Engelhard Corporation (Iselin, NJ) has developed similar technology for light-duty, diesel catalysts that meet the new Euro IV emissions regulation and that substitutes palladium for one-third of the platinum currently used in diesel engine autocatalysts. Production was projected to start in May 2005 on new cars for two major European automakers (Engelhard Corporation, 2005).

Outlook

An increase in diesel car sales in Europe can be expected to cause a strong increase in use of platinum in the region in 2004 and beyond. The tightening of emissions regulations in China, Europe, Japan, and other parts of the world is also expected to lead to higher average platinum loadings on catalysts, especially on light-duty diesel vehicles, as particulate matter emissions become more closely controlled. In the United States, thrifting is continuing at most manufacturers and is likely to lead to a reduction in the use of platinum in autocatalysts. The price differential of more than $600 per troy ounce between palladium and platinum has led to the assumption that automobile manufacturers will change PGMs ratios on gasoline-engine vehicles in favor of palladium, reversing the trend of the past 3 years.

Automotive industry use of palladium is expected to increase in the short term. Average loading levels on autocatalysts are expected to increase in Europe and Japan at the expense of platinum, as more stringent particulate emission standards are introduced. Now that U.S. automobile manufacturers have sharply drawn down their palladium stocks during the past year, purchases by U.S. automobile manufacturers are likely to increase. Many U.S. automobile manufacturers have yet to make the switch because of the history of high and volatile prices in the past. A shift towards greater use of palladium in preference to platinum on gasoline-vehicle autocatalysts by a number of manufacturers is also likely to provide a modest increase in palladium use in Asia and Europe. In Europe, however, production of gasoline fueled automobiles is expected to decline while sales of diesel engines continue to rise, and this will somewhat offset some of the expected growth from switching to palladium. As mentioned earlier, some U.S. manufacturers may also shift PGMs ratios more in favor of palladium, but this will be substantially offset by further thrifting. In the electronics sector, component sales are expected to increase. Increased demand for palladium, however, will be somewhat offset by a combination of miniaturization and substitution of nickel and silver for palladium in multilayer ceramic capacitors. The sales of platinum jewelry are expected to drop worldwide as the price continues to be high and white gold and palladium are substituted. In China, it is expected that the sale of palladium jewelry will increase as the price is lower than gold and platinum. Supplies of palladium and platinum are expected to increase significantly from new mines in South Africa.

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TABLE 1
SALIENT PLATINUM-GROUP METALS STATISTICS[1]

		2000	2001	2002	2003	2004
United States:						
Mine production:						
Palladium, Pd content:[2]						
Quantity	kilograms	10,300	12,100	14,800	14,000	13,700
Value	thousands	$228,000	$237,000	$162,000	$91,400	$102,000
Platinum, Pt content:[2]						
Quantity	kilograms	3,110	3,610	4,390	4,170	4,040
Value	thousands	$54,900	$61,900	$76,500	$93,100	$110,000
Refinery production:						
Palladium, Pd content:						
Quantity	kilograms	7,980	9,790	5,700	7,250 r	5,480
Value	thousands	$178,000	$192,000	$62,200	$47,300 r	$41,000
Platinum, Pt content:						
Quantity	kilograms	15,800	15,000	15,200	17,000 r	16,700
Value	thousands	$278,000	$258,000	$265,000	$379,000 r	$456,000
Imports for consumption, refined:						
Iridium, Ir content	kilograms	2,700	3,110	2,100	2,200	3,230
Osmium, Os content	do.	133	77	36	53	75
Palladium, Pd content	do.	181,000	160,000	117,000	105,000	127,000
Platinum, includes waste, scrap, and coins, Pt content	do.	93,700	84,200	84,700	88,500	86,400
Rhodium, Rh content	do.	18,200	12,400	8,630	12,000	13,200
Ruthenium, Ru content	do.	20,900	8,170	9,890	15,900	18,800
Exports, refined:						
Iridium, osmium, and ruthenium, gross weight	do.	390	252	94	145	677
Palladium, Pd content	do.	57,900	36,800	42,700	22,300	31,400
Platinum, Pt content	do.	25,000	29,300	27,800	22,200	20,000
Rhodium, Rh content	do.	797	982	349	479	311
Stocks, National Defense Stockpile, December 31:						
Iridium, Ir content	do.	784	784	784	562	501
Palladium, Pd content	do.	19,000	16,300	5,870	1,170	568
Platinum, Pt content	do.	5,190	3,680	649	649	649
Price, average:						
Iridium[3]	dollars per troy ounce	$415.00	$415.25	$294.62	$93.02	$185.33
Palladium[4]	do.	$691.84	$610.71	$339.68	$203.00	$232.93
Platinum[4]	do.	$549.30	$533.29	$542.56	$694.44	$848.76
Rhodium[4]	do.	$1,990.00	$1,600.00	$838.88	$530.28	$983.24
Ruthenium[3]	do.	$129.76	$130.67	$66.33	$35.43	$64.22
Employment		1,290	1,620	1,580	1,540	1,580
World, mine production, metal content	kilograms	364,000	395,000	414,000	452,000 r	467,000 e

[e]Estimated. [r]Revised.

[1]Data are rounded to three significant digits, except prices.

[2]Source: Stillwater Mining Co., 2004 annual report, p. 3.

[3]Price data are annual averages of daily Engelhard unfabricated quotations published in Platts Metals Week.

[4]Price data are annual Engelhard unfabricated quotations published in Platts Metals Week.

TABLE 2

U.S. IMPORTS FOR CONSUMPTION OF PLATINUM, BY COUNTRY[1]

Country	Grain and nuggets		Sponge		Other unwrought		Other		Waste and scrap		Coins	
	Quantity, Pt content (kilograms)	Value (thousands)	Quantity, Pt content (kilograms)	Value (thousands)	Quantity, Pt content (kilograms)	Value (thousands)	Quantity, Pt content (kilograms)	Value (thousands)	Quantity, Pt content (kilograms)	Value (thousands)	Quantity, Pt content (kilograms)	Value (thousands)
2003	849	$18,600	69,700	$1,480,000	7,210	$143,000	4,990	$89,700	5,670	$37,200	16	$426
2004:												
Argentina	--	--	--	--	70	1,990	--	--	--	--	--	--
Australia	(2)	7	--	--	--	--	893	24,300	2	1,420	7	199
Belgium	--	--	2,060	52,400	14	399	20	507	--	--	--	--
Brazil	--	--	207	3,840	--	--	--	--	1	18	--	--
Canada	27	698	--	--	1	18	421	11,200	1,370	7,730	3	82
Chile	--	--	--	--	--	--	--	--	3	198	--	--
China	--	--	5	132	--	--	2	18	13	420	(2)	7
Colombia	7	173	--	--	213	5,330	--	--	221	3,960	--	--
Dominican Republic	--	--	--	--	--	--	--	--	2	32	--	--
France	--	--	--	--	--	--	1	6	214	6,000	--	--
Germany	--	--	1,560	42,100	987	25,800	2,020	38,100	352	4,570	1	51
Hong Kong	--	--	--	--	--	--	--	--	20	535	--	--
India	--	--	25	315	--	--	--	--	--	--	--	--
Israel	--	--	--	--	11	314	--	--	--	--	--	--
Italy	18	495	693	17,600	711	16,100	78	2,160	8	176	(2)	5
Japan	--	--	23	549	83	2,210	697	18,500	605	11,500	--	--
Jordan	--	--	--	--	--	--	--	--	938	468	--	--
Korea, Republic of	--	--	--	--	172	4,910	8	205	476	6,140	--	--
Mexico	--	--	1	21	--	--	1	16	653	10,300	--	--
Netherlands	--	--	--	--	--	--	6	65	--	--	--	--
New Zealand	--	--	--	--	--	--	1	27	--	--	--	--
Norway	--	--	627	17,100	--	--	--	--	--	--	--	--
Philippines	--	--	--	--	1	20	5	110	69	1,540	--	--
Russia	--	--	1,370	37,400	3,280	88,800	--	--	--	--	--	--
Saudi Arabia	--	--	--	--	--	--	--	--	(2)	12	--	--
Singapore	--	--	--	--	--	--	--	--	10	406	--	--
South Africa	314	7,960	47,900	1,280,000	1,140	31,500	160	4,310	--	--	--	--
Switzerland	--	--	937	26,100	18	442	84	1,290	--	--	--	--
Taiwan	--	--	--	--	--	--	--	--	14	362	--	--
Ukraine	--	--	134	1,820	--	--	--	--	--	--	--	--
United Kingdom	11	183	13,300	353,000	3	91	154	3,850	897	26,200	--	--
Total	376	9,520	68,800	1,830,000	6,710	178,000	4,550	105,000	5,870	82,000	12	345

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Less than ½ unit.

Source: U.S. Census Bureau; data adjusted by the U.S. Geological Survey.

TABLE 3

U.S. IMPORTS FOR CONSUMPTION OF PLATINUM-GROUP METALS, BY COUNTRY[1]

	Unwrought palladium		Palladium, other		Iridium[2]		Unwrought osmium		Unwrought ruthenium		Rhodium[3]	
Country	Quantity, Pd content (kilograms)	Value (thousands)	Quantity, Pd content (kilograms)	Value (thousands)	Quantity, Ir content (kilograms)	Value (thousands)	Quantity, Os content (kilograms)	Value (thousands)	Quantity, Ru content (kilograms)	Value (thousands)	Quantity, Rh content (kilograms)	Value (thousands)
2003	83,500	$518,000	21,000	$145,000	2,200	$6,090	53	$430	15,900	$16,700	12,000	$202,000
2004:												
Belgium	5,190	36,000	190	1,490	--	--	--	--	--	--	1,580	46,600
Canada	2,290	22,200	87	851	(4)	2	--	--	--	--	(4)	3
China	33	285	--	--	--	--	10	68	--	--	1	22
France	--	--	15	69	--	--	--	--	--	--	(4)	4
Germany	1,350	10,200	2,050	18,100	47	320	4	66	2,050	4,090	1,080	34,000
Hong Kong	--	--	--	--	--	--	--	--	--	--	10	299
Ireland	--	--	--	--	1	7	--	--	--	--	--	--
Italy	161	1,400	950	8,070	3	21	--	--	--	--	6	203
Japan	3,260	13,200	1,840	3,280	--	--	--	--	--	--	17	700
Korea, Republic of	--	--	--	--	--	--	--	--	--	--	19	458
Netherlands	1	2	59	38	--	--	--	--	--	--	--	--
Norway	5,970	59,600	--	--	--	--	--	--	--	--	5	90
Russia	34,900	250,000	9,910	72,900	--	--	--	--	71	134	785	26,900
South Africa	29,200	213,000	97	642	1,080	4,390	61	288	16,500	31,200	6,340	178,000
Spain	15	107	--	--	--	--	--	--	--	--	--	--
Switzerland	4,080	32,500	3,380	24,300	--	--	--	--	--	--	420	17,400
Taiwan	45	100	26	32	--	--	--	--	--	--	--	--
Turkey	--	--	--	--	--	--	--	--	--	--	(4)	8
Ukraine	555	4,290	--	--	--	--	--	--	--	--	--	--
United Kingdom	18,800	143,000	2,070	14,800	2,110	13,200	--	--	194	410	2,920	92,400
Total	106,000	786,000	20,700	145,000	3,230	18,000	75	421	18,800	35,900	13,200	397,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Unwrought and other forms of iridium.

[3]Unwrought and other forms of rhodium.

[4]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 4

U.S. EXPORTS OF PLATINUM-GROUP METALS, BY COUNTRY[1]

Country	Palladium		Platinum		Platinum, waste and scrap		Iridium, osmium, ruthenium		Rhodium	
	Quantity, Pd content (kilograms)	Value (thousands)	Quantity, Pt content (kilograms)	Value (thousands)	Quantity, Pt content (kilograms)	Value (thousands)	Quantity, gross weight (kilograms)	Value (thousands)	Quantity, Rh content (kilograms)	Value (thousands)
2003	22,300	$110,000	22,200	$345,000	23,700	$377,000	145	$2,110	479	$15,100
2004:										
Argentina	--	--	70	1,770	--	--	--	--	(2)	3
Australia	343	2,080	661	18,800	--	--	--	--	--	--
Austria	--	--	9	128	--	--	--	--	--	--
Belarus	49	100	--	--	--	--	--	--	--	--
Belgium	22	144	8	196	--	--	--	--	(2)	4
Brazil	20	77	459	9,390	--	--	--	--	--	--
Canada	3,750	25,000	1,440	30,200	188	1,800	1	8	1	149
Chile	--	--	705	4,880	--	--	--	--	--	--
China	402	2,190	77	1,080	--	--	47	272	1	92
Czech Republic	7	21	13	272	--	--	--	--	--	--
Denmark	62	471	5	82	--	--	--	--	--	--
Finland	19	214	14	229	--	--	--	--	--	--
France	515	2,550	171	2,600	--	--	--	--	--	--
Germany	4,660	17,600	3,650	65,600	25	628	5	24	196	3,800
Hong Kong	4,240	28,100	1,030	15,000	--	--	33	151	3	538
Hungary	4	12	2	38	--	--	--	--	--	--
India	102	188	6	111	--	--	--	--	2	266
Ireland	1,020	2,560	110	1,630	--	--	1	3	--	--
Israel	1,230	3,550	3	55	--	--	--	--	--	--
Italy	239	1,570	141	3,640	--	--	--	--	--	--
Japan	1,140	4,570	4,550	92,600	1,280	31,400	2	19	103	2,190
Korea, Republic of	128	442	115	2,600	--	--	7	37	(2)	23
Liechtenstein	14	129	14	255	--	--	--	--	--	--
Malaysia	16	205	19	269	--	--	131	739	--	--
Mexico	97	498	312	5,520	--	--	1	38	2	210
Netherlands	2,560	7,370	47	712	--	--	--	--	--	--
Netherlands Antilles	--	--	2	40	--	--	--	--	--	--
New Zealand	68	585	4	52	--	--	--	--	--	--
Norway	47	531	15	243	--	--	--	--	--	--
Philippines	7	61	22	322	--	--	--	--	--	--
Poland	2	19	1	8	--	--	--	--	--	--
Qatar	1	3	--	--	--	--	--	--	--	--
Romania	--	--	6	73	--	--	1	5	--	--
Russia	2	18	1	17	--	--	--	--	--	--
Saudi Arabia	1	10	4	45	--	--	--	--	--	--
Singapore	33	291	32	656	--	--	28	149	(2)	30
Slovakia	28	75	--	--	--	--	--	--	(2)	3
Slovenia	70	131	--	--	--	--	--	--	--	--
South Africa	1	3	29	505	--	--	--	--	(2)	8
Spain	103	654	10	142	--	--	--	--	--	--
Suriname	--	--	3	55	--	--	--	--	--	--
Sweden	60	348	89	1,210	--	--	--	--	--	--
Switzerland	500	4,350	849	18,900	305	6,100	--	--	--	--
Taiwan	4,360	13,500	914	17,600	--	--	1	10	--	--
Thailand	65	457	35	509	--	--	1	6	2	391
Turkey	4	27	2	24	--	--	--	--	--	--
United Arab Emirates	--	--	1	6	--	--	--	--	(2)	15
United Kingdom	5,370	21,100	4,320	76,100	21,500	411,000	418	2,010	--	--

See footnotes at end of table.

TABLE 4—Continued

U.S. EXPORTS OF PLATINUM-GROUP METALS, BY COUNTRY[1]

	Palladium		Platinum		Platinum, waste and scrap		Iridium, osmium, ruthenium		Rhodium	
Country	Quantity, Pd content (kilograms)	Value (thousands)	Quantity, Pt content (kilograms)	Value (thousands)	Quantity, Pt content (kilograms)	Value (thousands)	Quantity, gross weight (kilograms)	Value (thousands)	Quantity, Rh content (kilograms)	Value (thousands)
2004—Continued:										
Uruguay	--	--	1	9	--	--	--	--	--	--
Other	20	122	2	41	--	--	(2)	3	(2)	75
Total	31,400	142,000	20,000	374,000	23,300	451,000	677	3,470	311	7,800

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Less than ½ unit.

Source: U.S. Census Bureau; data adjusted by the U.S. Geological Survey.

TABLE 5

PLATINUM-GROUP METALS: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Kilograms of metal content)

Country[3]	2000	2001	2002	2003	2004[e]
Platinum:					
Australia[4]	171	174	200 [e]	225 [e]	230
Canada	6,302	7,410	7,400 [e]	6,930 [r]	7,000
Colombia	339	674	661	1,393 [r]	1,400
Finland	441	510	508	505 [r]	500
Japan[5]	782	791	762	770 [r, e]	780
Poland[e, 6, 7]	21 [5]	20	20	20	20
Russia[e]	34,000	35,000	35,000	36,000	36,000
Serbia and Montenegro[e]	5	5	5	5	5
South Africa	114,459	130,307	133,796	151,022	160,013 [8]
United States[9]	3,110	3,610	4,390	4,170	4,040 [8]
Zimbabwe	505	519	2,306	4,400 [e]	4,438 [8]
Total	160,000	179,000	185,000	205,000	214,000
Palladium:					
Australia[4]	812	828	810	820 [e]	830
Canada	9,949	11,700	11,500 [e]	10,785 [r]	12,000
Japan[5]	4,712	4,805	5,618	5,500 [r, e]	5,600
Poland[e, 6, 7]	12 [5]	12	12	12	12
Russia[e]	71,000	72,000	73,000	74,000	74,000
Serbia and Montenegro[e]	25	25	25	20	20
South Africa	55,818	62,601	64,244	72,758	78,455 [8]
United States[9]	10,300	12,100	14,800	14,000	13,700 [8]
Zimbabwe	366	371	1,943	3,170 [e]	3,564 [8]
Total	153,000	164,000	172,000	181,000 [r]	188,000
Other platinum-group metals:					
Canada[e]	720	720	700	799 [r]	800
Russia[e]	14,100	14,500	14,500	14,600	14,600
South Africa	36,493	35,839	41,721	49,594	48,264 [8]
Zimbabwe	40	42	480	760 [e]	809 [8]
Total	51,400	51,100	57,400	65,800 [r]	64,500
Grand total	364,000	395,000	414,000	452,000 [r]	467,000

[e]Estimated. [r]Revised.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through April 29, 2005. Platinum-group metal (PGM) production by Germany, Norway, and the United Kingdom is not included in this table because the production is derived wholly from imported metallurgical products and to include it would result in double counting.

[3]In addition to the countries listed, China, Indonesia, and the Philippines are believed to produce PGM, and several other countries may also do so, but output is not reported quantitatively, and there is no reliable basis for the formulation of estimates of output levels. A part of this output not specifically reported by country is, however presumably included in this table credited to Japan.

[4]PGM recovered from nickel ore that is processed domestically. PGM in exported nickel ore are extracted in the importing countries, such as Japan, and are believed to be included in the production figures for those countries.

[5]Production derived entirely from imported ores.

[6]Based on official Polish estimates.

[7]Estimates based on reported platinum and palladium-bearing final (residual) slimes and then average Pt and Pd content from electrolytic copper refining.

[8]Reported figure.

[9]A very small quantity of byproduct platinum and palladium produced from gold-copper ores was excluded.